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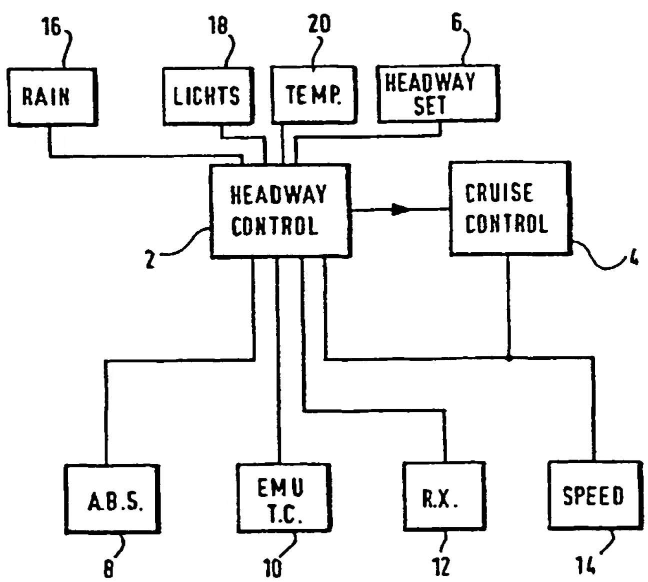

(57) Abstract

A headway controller (2) is provided for controlling the headway (distance to a target vehicle) used by a cruise control (4) in response to data indicative of vehicle system status, such as brake system status, or environmental conditions, such as ice, where it is prudent to increase the headway.

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METHOD OF AND APPARATUS FOR CONTROLLING HEADWAY

The present invention relates to a method of and apparatus for controlling headway of a vehicle controlled by a progress management system. A cruise controller represents an example of a progress management system. The headway is the gap, which can be expressed in distance or time between the vehicle being controlled by the progress controller and a target vehicle ahead of the controlled vehicle.

Vehicle cruise controllers have become increasingly sophisticated. EP 0612641A describes an improved control system in which a radar detector is used to identify the distance to and relative speed of a vehicle, hereinafter the target vehicle, travelling in front of a controlled vehicle. The cruise controller calculates a desired range to the target vehicle and uses this, in combination with the measured range, to calculate a range error. The range error and relative speed difference are then combined in a weighted manner in order to derive an acceleration demand signal which is used to control both the throttle and brake systems. The cruise controller will control the vehicle up to a set speed. However, if the vehicle under control approaches a slower vehicle from behind, the cruise control system will automatically decelerate the controlled vehicle in order to ensure that the controlled vehicle remains at a predetermined distance, the headway distance, behind the target vehicle without the need for driver intervention.

The desired range S is determined in accordance with the following function:

$$S = (0.23 \times V) + 7$$

Where the desired range S is given in metres and V is the vehicle speed in Kilometres per hour. In the absence of a constant 7 metres (which prevents the vehicle from following too closely at low speeds), the vehicle would be arranged to follow the target vehicle using a time separation of 0.83 seconds. However, for increased flexibility, the headway setting circuit is controllable by the driver so as to select any time separation, and hence desired range, within predetermined limits.

The distance to a target vehicle impacts on how quickly the controlled vehicle can perform an overtaking manoeuvre. Thus the driver may seek to reduce the headway to its minimum value when he anticipates overtaking one or more vehicles, or when driving in a "sports" mode. On other occasions, the driver may select a "normal" or "comfort" mode wherein the headway is increased compared to the sports mode.

The headway has a minimum value in order to ensure a margin of safety giving greater vehicle separation. However, there may be circumstances which develop where it may be advantageous to overrule the driver's headway setting in favour of a new headway.

According to a first aspect of the present invention, there is provided a headway controller for adjusting a desired headway on the vehicle controlled by a progress management system, wherein the headway is derived as a function of at least one measurement indicative of vehicle status or conditions external to the vehicle.

It is thus possible to provide an automatic headway adjustment, for use in advanced cruise control systems of the type described in EP 0612641A.

Preferably the headway is a function of the desired headway set by the driver, H_{set}, and one or more other inputs indicative of vehicle and/or external conditions.

Advantageously the headway controller is responsive to one or more vehicle systems. Thus if a self test routine establishes that a fault exists in a safety related system which may degrade the vehicle's performance or that of the cruise controller, then the headway may be increased. For example, if an error is detected in the anti-lock braking system, ABS, of a vehicle, then it can be assumed that the vehicle's braking performance will be diminished and consequently the headway should be increased. Similarly if vehicle sensors detect that the brake fluid is low, or that excessive brake-wear is detected for one or more of the vehicle brakes, or a brake is detected as running hot, then the headway should be increased.

Preferably the headway control is also responsive to systems which monitor environmental conditions or which are typically controlled by the driver in response to adverse environmental conditions. Advantageously the headway controller is responsive to a rain sensor carried by the vehicle and/or to a temperature sensor for ice detection. The occurrence of rain, ice or snow typically means that frictional contact with the surface over which the vehicle is travelling will be reduced and consequently the headway should be increased.

Advantageously the headway controller may also be responsive to vehicle sensors or systems which can derive a measure of surface roughness. Such systems may include an engine knock detector (which needs to filter out speed variations due to surface roughness), sensors in a vehicle suspension system, a steering input sensor which may be

responsive to vibrations transmitted back up the steering mechanism as a result of driving on an uneven surface, or by monitoring the error signal in a closed loop electronic steering system. In any event, once a rough road has been detected it may be assumed that braking performance will be adversely affected and consequently the headway should be increased.

Additionally or alternatively the headway controller may interface with a traction and/or stability controller which may hold an estimate of the coefficient of friction with the surface beneath the vehicle.

As a further possibility in addition to or an alternative to those described above, the system may be responsive to driver actuation of one or more vehicle subsystems, such as the windscreen wipers or the vehicle lights. Use of the windscreen wipers is indicative of rain. Similarly operation of the vehicle lights can be taken to be indicative of reduced visibility, either as a result of fog, rain or darkness, and in any event the headway should be increased in order to give the driver more time to respond to unexpected events. Optical detectors may also be provided to detect fog and rain and, additionally, may also detect when the sun is at a low angle such that the driver may experience difficulty in seeing surrounding objects.

Preferably the headway controller is arranged to activate an alarm when the vehicle's proximity detector, e.g. radar, provided as part of the cruise controller, detects the presence of a slow moving or stationary object ahead of the vehicle or another vehicle to close. The alarm function may be enabled only when the headway exceeds a predetermined threshold. The alarm may be audible, visual or both.

The headway controller may, optionally, be responsive to the time of day, thus, the headway may be slightly increased at those times when accidents are statistically more likely to happen as a result of driver fatigue.

The headway controller may also be responsive to signals monitoring the vehicle suspension which may indicate that the vehicle is heavily loaded, or badly loaded, and as a result the braking distance can be expected to increase. Similarly, the headway controller may also monitor connections, either continuously or before initiation, to a vehicle trailer socket in order to determine whether or not the vehicle is towing an item, and if so, to increase the headway to allow an improved margin of safety.

Preferably the headway controller may also be responsive to transmitted data representative of roadside events, such as details of traffic queues, accidents, roadworks and the like.

Additionally or alternatively, the headway controller may also be responsive to an onboard vehicle location and map system which may perform a look-ahead in order to determine expected road conditions. Thus, if a result of look-ahead indicates that the road will bend sharply, it will then be expected that the target vehicle will decelerate rapidly when its driver notices the turn. The controlled vehicle can anticipate this action by increasing its headway thereby allowing an improved margin of safety in the event that the target vehicle decelerates sharply.

According to a second aspect of the present invention, there is provided a method of controlling the desired distance between a controlled vehicle and a target vehicle, the

method comprising the steps of deriving data from one or more sensors indicative of vehicle status or environmental conditions, and calculating a desired headway as a function of the data derived from the sensors.

According to a third aspect of the present invention, there is provided a computer program product for causing a data processor to implement the method according to the second aspect of the present invention.

The present invention will be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 schematically illustrates a cruise controller, and

Figure 2 schematically illustrates the interconnection between a vehicle headway controller and a plurality of onboard vehicle subsystems.

Figure 1 schematically illustrates the interconnection between various vehicle systems for a vehicle generally indicated 1 equipped with an adaptive cruise controller, ACC, based on that described in EP 0612641A, which is incorporated herein by reference. A radar sensor provides data representing the speed and distance to one or more target vehicles. The cruise controller uses this information to derive an acceleration signal and a deceleration signal for controlling the engine and brakes of the vehicle.

As shown in the accompanying Figure 2, a headway controller 2 provides a headway signal to a cruise control 4. The headway control 2 is responsive to a driver actuated

headway set control 6 which enables the driver to adjust the headway between first and second limits, typically representing inter-vehicle delays equivalent to 0.8 to 4 seconds. The headway control 2 is also responsive to a status signal issued by a vehicle anti-lock brake system 8 which confirms that the anti-lock brake system 8 is functioning correctly, an estimate of road friction as derived from an engine management unit/traction controller 10, a radio receiver 12 which can receive traffic bulletins giving details of road works or queues, a vehicle speed sensor 14, and automatic rain detector 16, and the vehicle light system 18, which includes sensors for sidelights, headlights, and fog lights and outside air temperature sensor 20. Based on this information, the headway control 2 calculates the desired headway in accordance with the strategy described herein below and outputs this signal to the cruise controller 4.

The actual headway, H_{act} controlled by the system is a function of the driver selection and the input from other appropriate vehicle systems. Thus the headway can be generated by the formula:

$$H_{act} = H_{set} + \sum_{1}^{n} F(i_n).$$

Where:

H_{act} is the actual headway,

H_{set} is the headway selected by the driver, and

$i_1..i_n$ are the n inputs from vehicle subsystems from external sources.

In an alternative embodiment, the headway may be limited between the driver selected value H_{set} and a maximum headway value H_{max} in accordance with the following strategy:

$$H_{act} = \max((H_{set} + f(i_1) + f(i_2) + f(i_3) + \ldots f(i_n)), H_{max})$$

The functions $f(i_x)$ all produce a time, or in the alternative distance, value which may be zero or greater. Thus, one input (i_1) may be from a rain sensor. In dry conditions the value derived from this input will be zero. In light rain conditions, the value may be in the order of 0.2 to 0.5 seconds, whereas in heavy rain the value is likely to tend towards the maximum headway setting of the cruise control systems. The exact values produced are a matter of design preference for a particular vehicle and are chosen with reference to such parameters such as its braking ability and stability control. Another input (i_2) to the headway controller is the lamp status, i.e. on, sidelights only, dipped beam, full beam or fog lights on. Thus, if the fog lights are being used correctly, the fog lights will only be actuated when the driving conditions are foggy. Thus poor visibility can be inferred from the status of the fog light and used to provide an increased headway. This has the ancillary benefit in training drivers to switch their fog lights off when they are not required in order to reduce the headway. Thus, an input indicating fog lights are in use results in the headway calculation approaching the maximum headway value. An indication that sidelights are on would, however, only give rise to a small or even zero increase in the calculated headway distance.

A simple system which takes inputs only from a rain sensor and a lamp status indicator could operate with a range of headways from H_{min} to H_{max}, where H_{min} is the minimum headway that the driver can select and H_{max} is the maximum headway that the cruise control system can reliably tolerate whilst locking on to target vehicles. In such a system, the actual headway may be calculated by

$$H_{act} = \max((H_{set} + f(i_{lamps}) + f(i_{rain})), H_{max})$$

where:

$f(i_{rain})$ is the contribution from the rain sensor, and

$f(i_{lamps})$ is the contribution from the lamp circuit.

The range of values taken by $f(i_{lamps})$ could be in the range from zero to 3.5 seconds depending on which of the vehicle lamps is operated, and the range of values from $f(i_{rain})$ could be in the range of 0 to 3.0 seconds. The range of headway's which could be selected could range from 0.8 to 4.0 seconds and the maximum headway which the system could support could be 5.0 seconds. Thus the range of values which could be derived ranges from 0.8 to 5.0 seconds.

In a further embodiment of the system, correlation between various inputs could be used to provide a more appropriate headway control, since, in heavy rain lamps are frequently used. Thus if the head lamps are in a dipped mode and the windscreen wipers are operating at one of their higher speeds the contribution from these two factors would not be purely additive and may be arranged to have an increased cumulative value. Thus the headway could be calculated as

$$H_{act} = \max\left((H_{set} + f(i_{lamps}, i_{rain})), H_{max}\right)$$

Additional factors can be included in the headway calculation in a similar way.

In a further embodiment, the effect of additional factors can be used to derive a multiplication factor which is applied to the driver selected headway and which, would in turn reflect the driving preferences of the driver. This leads to a calculation of a form;

$H_{act} = \max((f(i_{lamps}, i_{rain}) * H_{set}), H_{max})$ or

$H_{act} = \max(((f(i_{lamps}) + f(i_{rain})) * H_{set}), H_{max})$

It is also possible to use additional inputs as a means to disable the system if conditions are deemed to be unsuitable for its use. For example, if the maximum possible headway that the cruise control system can support is exceeded by a margin of say, 50%, by the headway calculated from the weighted contribution of factors, then this is indicative that the cruise control system should be disabled. Alternatively, with the contributory factors presented as a multiplication factor, such a disabling of the system may be triggered by the multiplication factor being greater than a predetermined value.

As indicated, the system need not only be responsive to vehicle sensors, such as an ABS fault monitor, a rain sensor or a light sensor, but may also be responsive to external factors such as data transmitted by roadside beacons or radio stations to indicate that queues or slow moving traffic exist on a particular road. This data may then be compared with an onboard vehicle position determining system, if fitted, to be used to check if the vehicle is travelling on the affected road. If this is the case, an additional headway safety factor can be produced in order to ensure that the vehicle can respond safely to the requirement to slow or stop suddenly and/or that an appropriate warning can be issued to the driver.

It is thus possible to automatically update the vehicle headway settings.

CLAIMS

1. A headway controller (2) for adjusting the desired headway of a vehicle controlled by a progress management system (4), characterised in that the headway is derived as a function of at least one measurement indicative of vehicle status or conditions external to the vehicle.

2. A headway controller (2) as claimed in claim 1, characterised in that the headway is a function of a desired headway set by a driver of the vehicle and one or more other inputs indicative of vehicle and/or external conditions.

3. A headway controller (2) as claimed in claim 1 or 2, characterised in that the headway is bounded by a lower limit.

4. A headway controller (2) as claimed in any one of the preceding claims, characterised in that the headway is bounded by an upper limit.

5. A headway controller (2) as claimed in any one of the preceding claims, characterised in that the controller is responsive to vehicle sensors on a brake system or to a status indicator of a brake system or an anti-lock brake system (8) or a traction or stability control system.

6. A headway controller (2) as claimed in any one of the preceding claims, characterised in that the controller is responsive to at least one of a rain detector (16) an ice detector, and a thermometer.

7. A headway controller (2) as claimed in any one of the preceding claims, characterised in that the controller is responsive to vehicle systems (10) which derive a measure of surface roughness.

8. A headway controller (2) as claimed in claim 7, characterised in that the controller is responsive to at least one of an engine knock detector system (10) which derives a measurement of surface roughness, sensors in a vehicle suspension system, a steering input sensor and a steering error signal in a closed loop electric steering system.

9. A headway controller (2) as claimed in claim 7 or 8, characterised in that the headway controller is responsive to a traction and/or stability controller (10).

10. A headway controller as claimed in any one of the preceding claims, characterised in that the headway controller (2) is responsive to at least one of the actuation of windscreen wipers, rain sensors (16), vehicle lights (18), and optical detectors for detecting fog or the sun at a low angle, so as to detect conditions where the driver's visibility may be reduced.

11. A headway controller as claimed in any one of the preceding claims, characterised in that the headway is responsive to the time of day so as to increase headway during those times of day when accidents are more likely to happen due to driver error.

12. A headway controller as claimed in any one of the preceding claims, characterised in that the headway controller is responsive to connection of a trailer or to vehicle suspension system sensors to determine when a vehicle is heavily or badly loaded so as to increase the headway.

13. A headway controller as claimed in any one of the preceding claims, characterised in that the headway controller is responsive to data representative of roadside events (12).

14. A headway controller as claimed in any one of the preceding claims in which the headway controller is responsive to a vehicle position and navigation system such that the system can look ahead in order to determine forthcoming road conditions and to adjust the headway as a function thereof.

15. A headway controller (2) as claimed in any one of the preceding claims characterised in that the headway is generated as a function of a driver selected headway and a function of contributions from vehicle systems.

16. A cruise controller in combination with a headway controller as claimed in any one of the preceding claims.

17. A vehicle (1) including a headway controller as claimed in any one of the preceding claims.

18. A method of controlling the desired distance between a controlled vehicle (1) and a target vehicle, the method comprising the step of deriving data from at least one sensor indicative of vehicle status or environmental conditions, and calculating a desired headway as a function of the data.

19. A computer program product for causing a data processor to perform the method of claim 18.

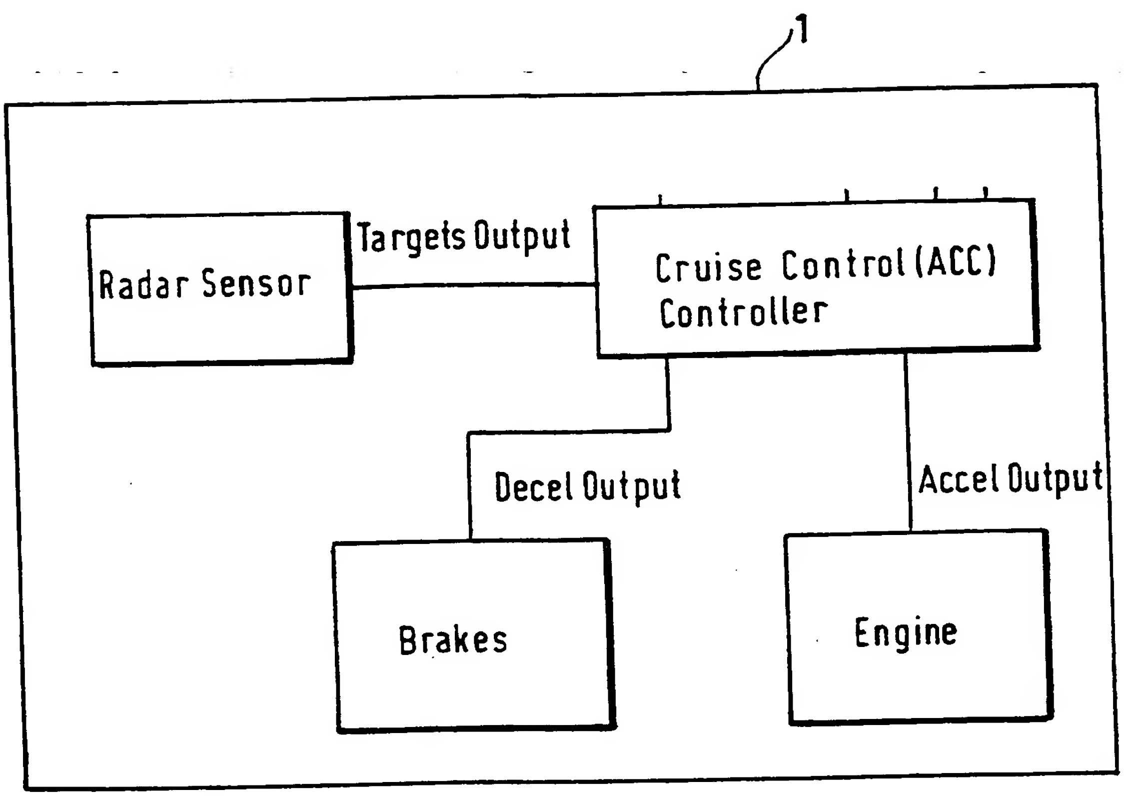
1
Radar Sensor
Targets Output
Cruise Control (ACC) Controller
Decel Output
Accel Output
Brakes
Engine

Fig.1.

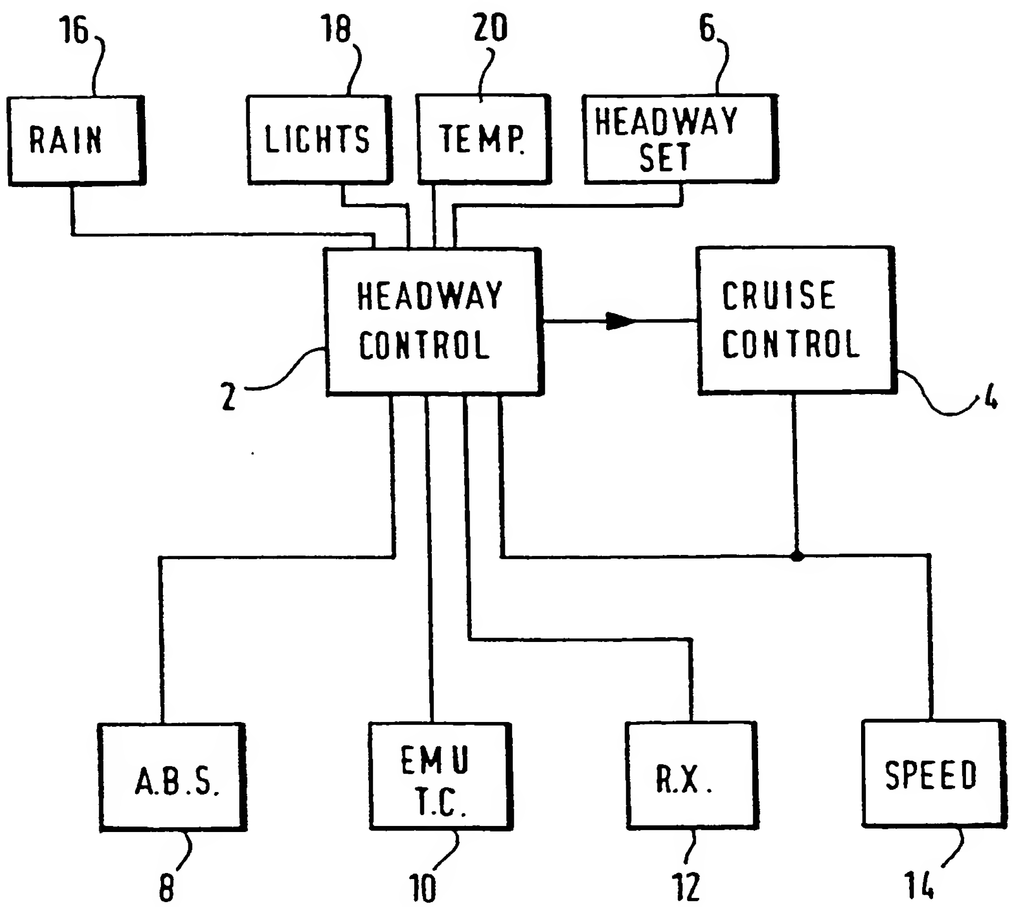
16
18
20
6
RAIN
LIGHTS
TEMP.
HEADWAY SET
HEADWAY CONTROL
CRUISE CONTROL
2
4
A.B.S.
EMU T.C.
R.X.
SPEED
8
10
12
14

FIG. 2.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/02604

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60K31/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B60K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
21 October 1999	27/10/1999

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International Application No
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